APS News

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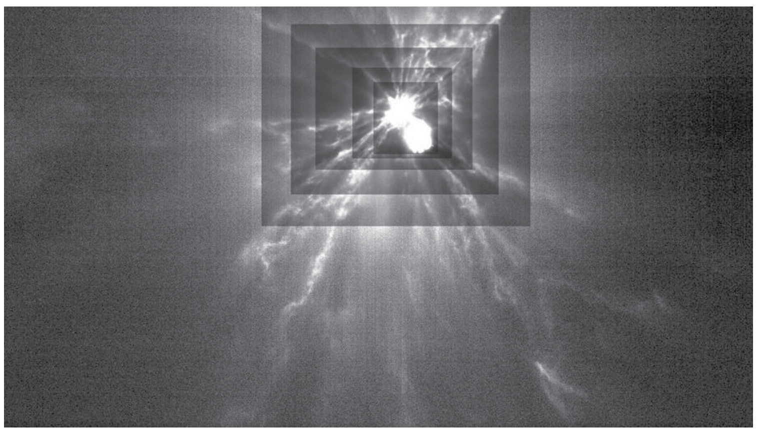
"I Get Goosebumps Still": Angela Stickle, DART Mission Scientist, Reflects on Humanity's First Effort to Change an Asteroid's Orbit

At an APS meeting in Chicago, Stickle coolly explained how smashing a spacecraft into an asteroid could someday save Earth — and, after last year's test, what comes next.

BY LIZ BOATMAN



This image, taken by the LICIACube satellite, shows the plumes of debris ejected from the Dimorphos asteroid after it was struck by the DART spacecraft. Each rectangle represents a different level of contrast. Credit: ASI/NASA/APL

In September 2022, space enthusiasts around the world played a 39-second video on repeat — the last moments of NASA's DART spacecraft before it collided with the asteroid Dimorphos, a "moonlet" of the larger asteroid Didymos.

In the eerie, silent footage, the spacecraft's approach looks slow. It wasn't. The force of the impact "was like a golf cart hitting a pyramid at 15,000 miles per hour," says Angela Stickle, a planetary geologist at the Johns Hopkins Applied Physics Laboratory (APL), who led the mission's modeling efforts.

In June, Stickle presented the results of her team's work at the 23rd Biennial Conference of the APS Topical Group on Shock Compression of Condensed Matter, held in Chicago.

The mission was a success: Dimorphos's orbit around Didymos was altered by 33 minutes. It was a test run for the theory that smashing a spacecraft into an asteroid could, in the future, shift its trajectory enough to keep it from colliding with Earth. In other words, DART, short for Double Asteroid Redirection Test, was the world's first test of planetary defense.

Key to this feat? Modeling. Stickle says one of the most important findings is that the code her team uses to model impacts, called "shock hydrocodes," gives similar results as

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As Undergrad Physics Enrollment Stumbles, Departments Look Inward

Faculty offer insight on how physics programs can showcase career paths, support students of color, and more.

BY LIZ BOATMAN

An undergrad hanging up a poster at the 2022 March Meeting. Credit: APS

The COVID-19 pandemic took a bite out of US undergraduate enrollment, which on average declined by 3.8% for men and 5.6% for women from 2020 to 2022.

But enrollment had already been falling. By the time COVID struck, enrollment nationally had already decreased by 13% — 2.6 million students — since its peak in 2011. And with a demographic 'enrollment cliff' predicted for 2025, many school administrators are nervously watching forecasts.

From 2000 to 2020, year-over-year increases in the number of physics bachelor's awarded in the US dipped below 150 students just three times: in 2008, 2009, and 2020. The first two, during the Great

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The Neurophysicist Trying to Tackle Jet Lag Ahead of the World's Longest Flights

Sveta Postnova wants to make 20-hour flights more bearable for travelers.

BY ALAINA G. LEVINE

Qantas Airlines, an Australian company, is planning the longest-ever flights for 2025. One physicist is working to make the experience better for flyers.

Most people don't like long flights, rife as they are with claustrophobic seating and loud neighbors. But one airline, Qantas, is about to unveil the longest flight routes ever planned. The flights — 20 hours from Sydney to London, 19 from Sydney to New York — will be unveiled in 2025, promising customers nonstop trips around the world.

One physicist is working with Qantas to make the long-haul flights more bearable for flyers. Dr. Sveta Postnova, Senior Lecturer in Neurophysics and Brain Dynamics at the University of Sydney, weaves together physiology, biology, and physics, studying sleep and circadian rhythms to uncover what might make the flights easier — for example, by minimizing jet lag, the bane of any globetrotter's travel.

She works in the field of neurophysics, the study of the brain using physics' techniques and tools. With an undergraduate degree in physics

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Teaching is a "Squishy, Unpredictable Science," Says the 2023 Physics Teacher of the Year. You Should Try It.

Joe Cossette, engineer-turned-educator and PhysTEC Teacher of the Year, discusses trials and triumphs in the classroom.

BY TARYN MACKINNEY

Joe Cossette just won a big award, and he feels a little weird about it.

"Teaching is a communal pursuit," he says. "It feels odd to get individual recognition."

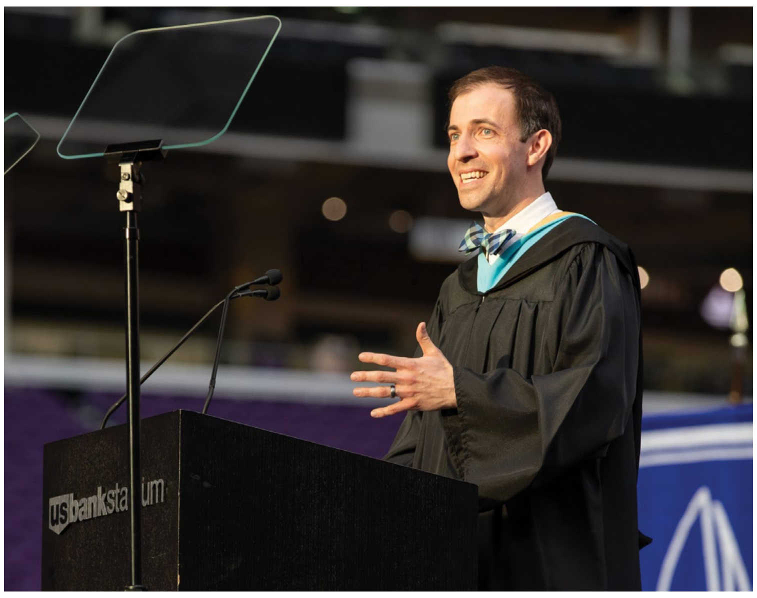
Cossette, a Minnesota native, bowtie superfan, and International Baccalaureate (IB) physics high school teacher at Minnetonka High School in Minnesota, was named the 2023 PhysTEC Teacher of the Year, an award that recognizes outstanding physics educators.

Although it's an honor, he says, "I feel like my ideas are just iterations of someone else's cool idea."

But Cossette's iterations are remarkable, from virtual labs to physics murder mysteries. In just five years, he helped grow the school's IB physics classes from 12 students to 120 students. His website, Passionately Curious Science, where he shares lesson plans and tips, attracts 90,000 visitors each year.

Teaching is hard work, but "I get to play all the time," he says. He certainly seems to have fun: Consider his physics-themed parody of the singer Adele's 2015 hit "Hello" ("Hello, it's 'v'... Take the distance over time, to calculate velocity...").

APS News spoke with Cossette about his career path and thoughts on the profession. This interview has been edited for brevity and clarity.



Joe Cossette gives a commencement address to the Minnetonka High School graduating class of 2022. Credit: Minnetonka Public Schools

You worked as an engineer before you became a teacher. Why the shift?

I went to college for mechanical engineering and then worked for a couple years as a mechanical development engineer. I enjoyed it, but my favorite day of the year was being a guest judge at the state science fair. I was having a ton of fun, and I realized that could be my whole job — to talk to students and get excited about the science they're excited about.

I looked up programs at the University of Minnesota for people that already had a four-year technical degree, but needed the education piece. It felt right, so I made the switch.

I'm going into year 10 of teaching. I teach ninth and 12th grade, so I bookend their science career.

I've heard you're famous for wearing bow ties. Why bow ties?

I started as a fairly young teacher, teaching mostly seniors in a large school — 3,500 students. I wanted a way that people could realize I was not a student. I thought, "I can wear a bow tie. A student wouldn't wear a bow tie." Now I'm up to at least 50 bow ties. My goal every year is to make it as long into the school year as I can before I re-wear a bow tie.

How would you describe your approach to teaching?

The overarching theme is collaboration — whether creative group

Joe Cossette continued on page 3

Nick Wise, Scientific Sleuth and Fluid Dynamics Researcher

Wise spots awkward phrasing and other red flags to identify fraudulent research papers.

BY DALMEET SINGH CHAWLA

Alongside his research in engineering and fluid dynamics at the University of Cambridge, Nick Wise has what he calls a "weird hobby." Every day, he spends around an hour as a scientific sleuth, trawling through research papers to sniff out potential fraud and misconduct.

Nick Wise

Wise was inspired by other prominent sleuths. Elisabeth Bik, for example, gave up her microbiology career to devote her time to spotting unethical image manipulation, primarily in biomedical literature. And Guillaume Cabanac, a computer scientist at the University of Toulouse in France, has worked with colleagues to study tortured phrases — awkward wording that often results from plagiarists using automated software to translate papers into English and publish them as their own.

APS News spoke with Wise about his detective work and hopes for the future.

What was your first step in investigating research integrity?

My interest began in summer 2021 during my doctoral studies. I got started by going to a paraphrase widget online and plugging in the term "heat transfer." Out came the phrase "warmth move." I searched for that in quotation marks using the Problematic Paper Screener, a tool developed by Cabanac and colleagues that sifts through published papers and flags any containing tortured phrases. Once you find a paper that's got a tortured phrase, it probably has other phrases, and then that gives you a new term to search. It was easier to find papers in my own field because I know what the correct phrase should be. Every field has its own jargon.

What did you do once you found those suspicious studies?

I started to flag the papers on PubPeer, an online platform where scientists discuss scientific papers. Then I started to see what kinds of problems other people were flagging, including mass self-citations, citation manipulation [unethical attempts to boost one's own citation counts], and all sorts of other ways in which one can corrupt the literature and commit misbehaviors. In some instances, you don't need to be an expert or working in the field to identify that there's something wrong.

My work has led to [one publisher] retracting around 850 papers, most of which are conference proceedings. A lot of those have multiple problems, including tortured phrases, citation manipulation, plagiarism, and manuscripts originating from paper mills [people or organizations that produce bogus studies in exchange for a fee so researchers can gain easy publication].

Is it getting easier for plagiarists to avoid using tortured phrases?

Even pre-ChatGPT paraphrasing software had advanced sufficiently that it didn't produce many tortured phrases. With ChatGPT, there's no need to paraphrase at all, so there will be none. However, there are thousands of published papers with tortured phrases, and I would like

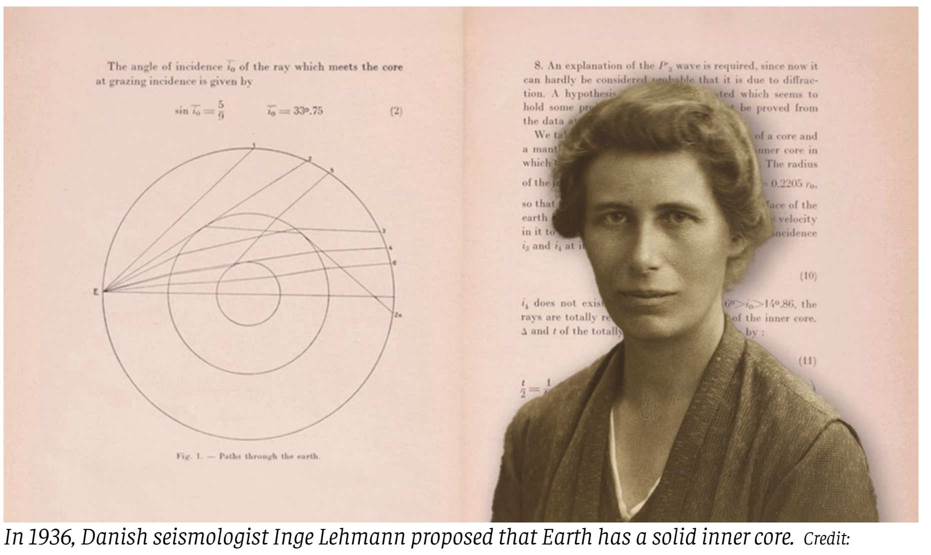
Nick Wise continued on page 4

THIS MONTH IN PHYSICS HISTORY

September 1936: Seismologist Inge Lehmann Concludes That Earth Has an Inner Core

By carefully studying earthquake shock waves, Lehmann realized that the prevailing view of Earth's structure was incomplete.

BY LIZ BOATMAN



In 1936, Danish seismologist Inge Lehmann proposed that Earth has a solid inner core. Credit: *Background drawn from pgs. 88 and 97 of Lehmann, I. (1936): P', Publications du Bureau Central Seismologique International, Série A, Travaux Scientifique, 14, 87–115. Foreground is public domain.*

In the early 1900s, scientists were pondering a tricky question: What lies deep — very deep — beneath our feet? Relying on seismographs, which measure the shock waves of earthquakes, geophysicists had assumed that the Earth's core was a hot, molten sphere. But the theory had holes, failing to explain stray waves measured in unexpected places.

Then, in September 1936, a Danish geophysicist named Inge Lehmann published a paper, succinctly called "P'," arguing for what scientists now take for granted: That buried inside the Earth's molten layer is a solid core.

> "We take it that, as before, the earth consists of a core and a mantle, but that inside the core there is an inner core in which the velocity is larger than the outer one."— Inge Lehmann

Born in 1888, Lehmann attended the first coeducational school for children in Denmark, run by Hanna Adler, aunt of physicist Niels Bohr. At Fællesskolen, boys and girls alike learned traditional subjects, like math and science, as well as crafts like woodworking and needlepoint. "No difference between the intellect of boys and girls was recognised," she wrote later, "a fact that brought some disappointment [to me] later in life when I had to recognise that this was not the general attitude." (There were few women in science in Lehmann's era.)

After completing a mathematics degree at the University of Copenhagen in 1920, Lehmann spent a few years working as an assistant for an actuarial science professor. But she had also taken chemistry, physics, and astronomy courses during school, and found the topics interesting.

At the time, many geologists, geodesists (who study Earth's geometry), and seismologists were captivated by questions of Earth's geological history and structure. One of these scientists was Niels Erik Nörlund, the director of the Danish geodetic institute, the Den Danske Gradmaaling. In 1925, he invited Lehmann to work as his assistant. Nörlund was on a mission to construct the most advanced and most accurate seismograph stations in the world, building a network throughout Denmark and Greenland to study earthquakes.

At the time, Lehmann knew little about earthquakes. "I may have been 15 or 16 years old when, on a Sunday morning, I was sitting at home together with my mother and sister, and the floor began to move under us," she wrote in a 1987 article. "This was my only experience with an earthquake until I became a seismologist 20 years later."

Working with Nörlund, Lehmann learned that seismographs, which record shock waves, enabled scientists to pinpoint an earthquake's origin, or epicenter. And because waves move differently through different materials, "knowledge of the earth's interior composition could be obtained from the observations of the seismographs," she wrote — a roundabout way to peer inside the planet, since no direct samples could be taken from so far beneath the surface.

An exceptional mathematician, Lehmann took the calculations quickly. By the late 1920s, Lehmann's expertise in seismographic interpretation had led her straight to an unsolved problem in geophysics.

Seismic data had long recorded two types of waves. P-waves, or pressure waves, cause matter to compress and expand in the direction the waves are traveling. P-waves can move through solids, liquids, or gases. S-waves, or shear waves, are different — they cause matter to slide across itself, perpendicular to the wave's direction of motion, and they can only travel through solid matter or some extremely viscous liquids.

Because pressure waves travel faster in solids than in liquids, the trajectory of an earthquake's P-wave "bends" as it moves from Earth's solid mantle into its liquid core, similar to how light bends through a prism.

Since the late 1880s, seismologists had observed that, unlike P-waves, S-waves could not be detected on the other side of the world from an earthquake epicenter. Something inside Earth was stopping them in their tracks. In 1926, British geophysicist Harold Jeffreys concluded that Earth must have a liquid core, which prevented the S-waves from passing through. Jeffreys' model also meant that P-waves shouldn't make it to certain places on the other side of the world: The waves, bent as they traveled through the liquid core, created "shadow zones" — patches far from the epicenter that waves didn't reach.

But there was a problem: Newer, better seismographs *were* detecting P-waves in shadow zones. They were few and faint, and geophysicists treated them as errant. German seismologist Beno Gutenberg, for example, called them "diffracted waves, with no explanation given," Lehmann wrote.

Then, in 1929, a massive New Zealand earthquake provided more concrete proof: P-waves had undeniably been detected in the earthquake's

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APS's Newest Physical Review Journal, *PRX Life*, Publishes Its First Issue

BY TARYN MACKINNEY

A fruit fly, the species at the center of a study in PRX Life*'s first issue.*

PRX Life, an interdisciplinary, open-access journal focused on quantitative biological research, celebrated the publication of its inaugural issue in late July.

"At the intersection of the physical and living worlds lie remarkable questions about the origins of life, the rules by which living systems evolve, and the nature of complex biological behaviors," wrote Managing Editor Serena Bradde and Lead Editor Margaret Gardel in their first editorial. "The research community at this intersection is now a thriving academic discipline across physics, engineering, neuroscience, molecular biology, cell biology, ecology, and beyond."

The first issue of *PRX Life* is, like the fields it represents, diverse. In one study, researchers show that fluctuations in the rhythmic beating of a sperm cell's tail can shed light on the tiny motors inside (C. Maggi et al., *PRX Life* 1, 013003). In another, researchers reveal how special contractile proteins help tissues form in fruit fly embryos (R. Marisol Herrera-Perez et al., *PRX Life* 1, 013004).

The journal's high standards stem in part from its rigorous review process, including a collaborative peer review model, in which referees comment on each other's reports before an editorial decision is sent to authors.

PRX Life is now accepting submissions of impactful research studies at the interface of physics and biology. Learn more at journals.aps.org/prxlife.

Taryn MacKinney is the Editor of APS News.

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work, like a murder mystery or an escape room, or a quiz that adds layers of collaboration throughout. Sometimes it takes a while to build trust, where students are willing to go along with a crazy idea I have. But that's my goal.

I also try to be conscientious of common, destructive tropes. For example, a lot of people have an idea of what a physicist "looks like." That trickles down to students, who have learned, often before they get to my class, that they are or are not what someone looks like or is like to succeed in physics. That's frustrating because if all physicists were of one style, we would be missing out on important discoveries.

Often, the students left behind are the students seen as more liberal-arts-minded. In my classroom, I value students who think in creative ways and see the problem as not just a math equation, but as a story, or find a new way to represent an idea. That is what we've done." Now we're giving them four years of folders, where every folder is different, and saying, "We'll probably pick from these things." It's been an interesting challenge.

Are there students you taught who pursued physics or teaching after high school?

I have one or two students each year that didn't really know what physics was but leave planning on majoring in physics. I'm always nervous that their experience in college is going to be different than their experience in my classroom, but I'm excited to hear from those students.

I also have a former student who is starting her first year of physics teaching next year. I've talked with her a number of times, and she's part of an IB physics class Facebook group. I see her posting things to share with others, and it's just very exciting.

> "I'll do the same thing in second and third period and get dramatically different results, because my students aren't robots and don't learn in the same ways." — Joe Cossette

What topics are most exciting to you personally?

The IB curriculum allows us to cover a large breadth of content, and I've gotten to teach particle physics and astrophysics, which is not something I ever learned. I approach it as a learner, like they do — I was trying to figure out how to share the thing I'm learning now with students tomorrow. That changed the way I teach all things, because it reminds me of the challenges and motivations of learning.

Another topic is climate change. High school students know it's important; you don't have to convince them. Getting to talk about something they already want to know more about has been a joy.

What day-to-day challenges do you face?

Teaching is a squishy, unpredictable science. I'll do the same thing in second and third period and get dramatically different results, because my students aren't robots and don't learn in the same ways.

The most challenging thing is finding ways to meet the different needs in my classroom. Sometimes it's based on background knowledge. There are students that come in with a strong math background and students who do not, and their needs are different. I need to be able to provide the right scaffolding, so each of those students can understand the things we're talking about.

COVID has added to that in unpredictable ways. My seniors last year were in ninth grade when we went online for COVID. I saw incorrect answers I had never seen before — math errors that had never come up. It was because of holes in their experience in ninth or 10th grade algebra.

Are there lessons from teaching during the pandemic that you've carried into your classroom today?

It feels like drinking from a firehose sometimes. We have stuff we built before COVID and during COVID, and now we're constantly choosing between them. Do we do this stuff from four years ago that we loved, or do we do the thing that we built brand-new two years ago and loved? Did it work because it was online, or because it was a good task?

Before, we could just provide new teachers with a folder and say, "This

As you know, the US has a shortage of high school physics teachers. Have you personally experienced this?

I'm fortunate — my school is kind of a unicorn school for physics teachers. In our science department, 10 of us have a physics teaching license. Not a common story, right? Most physics teachers that I come across are often the only one in their school. That's an isolating position to be in.

Something that I think helps with that is finding ways to connect with other physics teachers. I've found physics communities through Twitter and Facebook and email lists, or within a small district area. In Minnesota, we have GO4ST8 Physics. All the physics teachers in the state can get together and talk physics every other month.

But that doesn't necessarily recruit teachers. It helps teachers once they're teaching, but nobody is going to go into teaching because an online community of teachers exists.

What *would* help with recruitment?

I think people go into teaching physics because they see it's fun. I'm constantly learning and getting to play, and that's just fun. I didn't feel like I got that as an engineer, but I do as a teacher. Being able to share those stories, I think, is how people become teachers.

And I still get to interact with all the different topics within physics. When I was working as an engineer, I became specialized and didn't get to do that.

In addition to being able to explore all these different realms, I get to introduce them for the first time to someone else. I'm a dad to a three- and five-year-old, and I love taking them to places that I enjoyed as a kid, like the amusement park in the Twin Cities. I get to re-experience, through them, what it's like to see it for the first time.

In teaching, I get to do that all the time. I've taught the same lessons many times, but every time is the students' first time. I get to see it with them. That's really fun to do, and I wish I could share that with more people.

Taryn MacKinney is the Editor of APS News.

Learn about the Physics Teacher Education Coalition (PhysTEC) at phystec.org.

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shadow zones. Lehmann, poring over the new earthquake data, was perplexed. If indeed Earth had only a mantle and a liquid core, why did P-waves reach those zones?

Then she had an idea. Perhaps another layer in Earth's core was interacting with the waves — a core nested within a core. She revised seismologists' working model of Earth and, in September 1936, published her theory in a paper titled simply "P′" (The prime denoted waves that had passed from the mantle into the core). In it, she wrote, "We take it that, as before, the earth consists of a core and a mantle, but that inside the core there is an inner core in which the velocity is larger than the outer one."

The theory solved the problem of the P-waves "emerging at distances where it had not been possible to predict their presence," she wrote later.

To Gutenberg, Lehmann had found the missing piece of the puzzle. Jeffreys wasn't convinced until 1939, when other seismologists carried out calculations with more accurate data and confirmed that Lehmann's model matched their experimental observations.

In the 1940s, other geophysicists proposed that the innermost core was solid, as Lehmann's paper had implied. And in 1952, geophysicist Francis Birch published a detailed study that concluded Earth's inner core must be solid — probably crystalline iron.

Lehmann went on to serve as chief of Gradmaaling's seismological department until she retired in 1953. During those years, she published 35 papers. Even in retirement, she continued her research, directing her interests toward the Earth's mantle.

Ultimately, it was Jeffreys who, in a letter to Niels Bohr in 1962, suggested that Lehmann's discovery of Earth's inner core deserved to be honored in her home country of Denmark. In 1965, Lehmann was awarded the Gold Medal of the Danish Academy of Sciences and Letters.

In 1971, Birch awarded Lehmann with the American Geophysical Union's highest honor, the Bowie Medal. He remarked that Lehmann's 1936 revelation "was discovered through exacting scrutiny of seismic records by a master of black art for which no amount of computerisation is likely to be a complete substitute" — a reference to the incredible number of hand calculations that Lehmann had performed.

In her honor, the geology community named the boundary between the Earth's inner core and outer core "the Lehmann discontinuity."

Lehmann died in 1993, at the age of 104, making her one of history's longest-lived scientists. Her last writing, a manuscript called "Seismology in the days of old," was published six years before her death, in 1987. It closed with words that still ring true today.

"The first results for the properties of the inner core were naturally approximate," she wrote. "Much has been written about it since, but the last word has probably not been said."

Liz Boatman is a staff writer for APS News.

Two New Anthologies Will Share the Stories of Women in Fluid Dynamics

BY TARYN MACKINNEY

A 13-year-old grassroots effort to support women in fluid dynamics has taken a creative turn.

The Women in Fluids Networking Group, started in 2010 by members of APS's Division of Fluid Dynamics (DFD), are planning to publish two anthologies of creative nonfiction aimed at inspiring girls, women, and femme-identifying individuals to pursue careers in fluid dynamics. The initiative, called Stories of Women in Fluids (SoWiF), seeks to publish anthologies online and in print by early next year.

The first anthology, geared toward children aged 8-12, will consist of short, age-appropriate nonfiction stories — written by members of the initiative — about the writers' experiences in science. The second anthology will aim to reach early-career female professionals in fluid dynamics, sharing contributors' personal narratives about their careers and offering advice to other women.

One anthology will be geared toward girls ages 8-12.

Both anthologies aim to provide a written guidepost for mentorship, and to inspire girls and women to pursue careers in the field.

The SoWiF initiative will host a mini-symposium at the APS DFD meeting, which takes place in Washington, DC, on Nov. 19-21 this year. Cosmic Writers, a nonprofit that provides writing workshops, have provided training for the anthologies' authors as they put pen to paper.

The initiative was boosted by an APS FOEP mini-grant and an anonymous donation, but much work remains. Interested in supporting or joining the initiative, spreading the word, or sharing your own stories for future anthologies? Please email storiesofwomeninfluids@gmail.com. To attend the mini-symposium in Washington, DC, this November, visit www.2023apsdfd.org.

Taryn MacKinney is the Editor of APS News.

Congress Scrambles to Steer AI Development

BY MITCH AMBROSE

While talk of artificial intelligence has been humming in Congress for years, this spring's launch of powerful language-generation models and chatbots has triggered a frenzy of activity on Capitol Hill.

In June, Senate Majority Leader Chuck Schumer (D-NY) announced that he plans to develop legislation to steer the development and use of AI, adhering to what he calls a "SAFE Innovation Framework." The goal: Develop AI technology in ways that safeguard national security, ensure accountability for misuse, align AI systems with democratic values, and ensure AI systems can explain how they draw conclusions.

Schumer plans to convene "insight forums" starting this September to supplement more traditional committee hearings. "We need the best of the best sitting at the table — the top AI developers, executives, scientists, advocates, community leaders, workers, national security experts — all together in one room, doing years of work in a matter of months," he said. Schumer has picked Sens. Martin Heinrich (D-NM), Mike Rounds (R-SD), and Todd Young (R-IN) to help lead the Senate's development of AI legislation. Heinrich and Rounds co-chair the Senate AI Caucus, and Young was the lead Republican co-sponsor of Schumer's innovation policy push last Congress, which resulted in the CHIPS and Science Act.

Pieces of potential bills have begun to emerge. In July, Heinrich and Rounds introduced legislation to create a National AI Research Resource (NAIRR), which would give US researchers access to data and computational resources necessary to develop new AI technologies. The legislation envisions the National Science Foundation as the lead agency for the NAIRR, following the recommendations of a congressionally mandated task force.

Senators have also attached a host of AI-focused proposals to their versions of the annual National Defense Authorization Act, many of which are likely to make it into the final version of the bill negotiated with the House.

House Speaker Kevin McCarthy (R-CA) has not announced an analogous AI initiative, but several House committees have taken up the subject. In June, the House Science Committee held the first of a series of hearings on AI to inform a

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other codes developed by researchers around the world.

"A lot of these have grown up independently, but we're finding that they all work the same for these kinds of problems," she says. "We can utilize a broader community to do some of this work." Planet-wide collaboration for planet-wide defense.

Stickle's interest in impact physics began as an undergrad at the University of Washington. She chose it for its aerospace program, but when she took a geology class, she got hooked on rocks. "I basically fell in love with [geology]," she says.

After an internship at the Jet Propulsion Laboratory in California, she knew she was interested in planetary geology. She enrolled in graduate school at Brown University, where she got her first taste of impact physics. "My research was both in experiments and in simulations," she says. "A lot of what I was interested in was how things break."

Eventually, she landed at the Johns Hopkins APL. One day at lunch, she and a few colleagues were "tossing ideas around," discussing whether it would be possible to crash a spacecraft into an asteroid and redirect its orbit. The idea grew into a mission concept study, "which essentially means we had a little bit of money to look at it and see if it was feasible," Stickle says.

By 2015, the concept had gained momentum, and the DART mission was born. Given her work on the mission concept study, Stickle was tasked with leading the impact modeling working group.

She brought together collaborators from around the world to carry out a range of studies, "to understand what we could expect from DART prior to impact." It was tricky work. "The processes that we're talking about are big," she says. "Constructing an experiment that can faithfully represent that type of process — it's not always easy."

Finally, in November 2021, the DART craft was launched into space aboard a SpaceX Falcon 9 rocket.

On Sept. 26, 2022 — nearly a year later, after the spacecraft had traveled some 7 million miles — Stickle's team stood by and braced for impact. "It was incredible. We had the livestream on that NASA was broadcasting," she recalls.

They watched the feed from DART's camera as the spacecraft raced toward Dimorphos. The asteroid, at first a distant gray speck, grew closer and closer until its rocky surface filled the screen. Then, impact — the feed stopped.

"I get goosebumps still, every time I watch those videos," says Stickle.

From a safe distance away, LICIACube, a tiny "CubeSat" satellite developed by the Italian Space Agency that had flown with DART across the solar system, snapped post-impact images. Those images revealed that the impact was powerful enough to spew debris, including boulder-sized rocks, in every direction. "The ejecta from the impact crater was a little bit of a surprise," Stickle says.

Since then, Stickle's team has been working with the post-impact data, using simulations to probe the asteroid's structure. Next, they'll apply what they learn to new impact studies. Their work could shape the development of technologies that could save Earth from rogue asteroids.

Objects already regularly collide with Earth. Friction in the atmosphere usually burns up smaller objects, creating the vibrant displays we call "shooting stars" and meteor showers, but Earth's surface has also been scarred by more devastating collisions. Some have left craters large enough to be seen from space, like the Chicxulub crater on Mexico's Yucatán Peninsula, thought to be the site of the asteroid impact that killed off the last dinosaurs.

Should we be concerned about an impact like that in our lifetimes? "The odds are very, very low," says Stickle. "Part of the planetary defense program is to find all the potential threats. NASA has a lot of telescopes on the Earth and in space looking for objects that could be a threat."

"We have not found any that are on a course to collide with the Earth in the next hundred years," she says.

Stickle says NASA will soon launch the Near-Earth Object Surveyor Mission, to look for smaller objects that could still pose a threat. And NASA isn't the only entity involved in trying to keep Earth's inhabitants safe from asteroids. The European Space Agency is preparing the Hera mission, to rendezvous with Dimorphos and Didymos. And the United Nations runs international committees on the topic that include countries from all over the world.

Stickle says it's a good thing the United States isn't "alone" in this effort to keep the planet safe from space impacts. "We definitely need the world to be invested in this sort of technology."

Liz Boatman is a staff writer for APS News.

To learn more about the SCCM topical group, visit engage.aps.org/gsccm/home.

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publishers to go back and clean up the literature where necessary.

Which aspect of misconduct is of most interest to you now?

I've come across many Facebook posts selling authorship slots for manuscripts that are already accepted to be published in journals. Some of these contain the paper's title, so if you Google that a few months after, you can match the advertisement to the final published paper.

There are lots of different entities committing various levels of fraud. Some companies have their own brand, and then there are individual authors posting on Facebook that if someone will pay $1,000, they can be the first author of their paper.

Although some websites that sell authorship slots are sophisticated in not mentioning the titles or abstracts of forthcoming papers — making them difficult to track and match with the resulting papers — many aren't so careful. For instance, they often include the title, authorship position, and journal impact factor, which you can cross-reference to confirm your suspicions. The higher the impact factor, the higher the price.

What trends have you spotted among researchers buying authorship slots?

Because some people are repeat customers for these sites, a pattern starts to emerge about their publication record. For instance, [a journal] recently retracted a paper after I revealed a Facebook post that advertised several author positions on it. One of its authors published 50 papers last year on a range of different disciplines, despite barely publishing anything before that.

What's the solution to this and other kinds of misconduct?

What seems to be happening is that authorship slots are being sold after papers are accepted for publication, perhaps with minor revisions. When revisions are submitted, extra researchers are added on the author lists. Enough editors are sufficiently naive or complicit to allow many authors to be added on a single paper and not question why a physiotherapist in Thailand is suddenly on a paper about nanoscience with researchers from Iraq and Russia.

It would make it harder for people selling authorship if they had to submit a paper after selling their authorship slots, because the paper could get rejected and they would have to start the process again. Similarly, if authors are adding references after the paper has been accepted at the proof stage, this needs to be flagged and investigated.

What are you working on when you're not doing detective work?

I'm looking for my next research position to continue my fluid dynamics research and trying to get my first permanent position. Such is the way of the early-career researcher. I intend to keep investigating research fraud. It doesn't look like we're going to run out of problematic research any time soon.

Dalmeet Singh Chawla is a freelance science journalist based in London.

Postnova continued from page 1

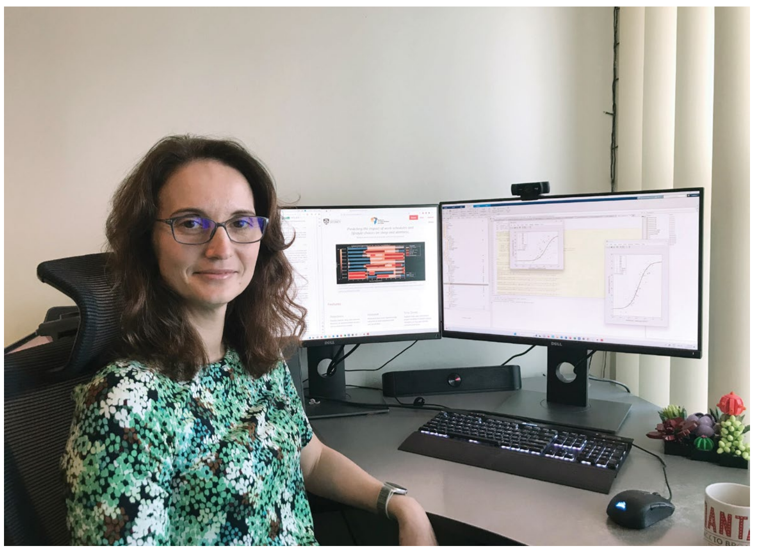
and PhD in computational neuroscience, Postnova is up to the long-flight challenge: She is an expert in chronophysics, a term she coined to describe research in the biophysical modeling of circadian rhythms, which determine sleep and hormone cycles.

She started partnering with industry almost 10 years ago, when she was invited to propose a project for a Cooperative Research Centre (CRC) in Australia, a consortium that supports collaboration between university researchers and companies. Postnova worked for seven years with a CRC that focused on alertness research. "I learned how to navigate this space," she says.

In 2015, Qantas approached Postnova with a problem to solve: The airline, which was planning a 17-hour, Perth-to-London nonstop, wanted to know how best to schedule in-flight activities.

Aboard a typical long-haul flight, the cabin stays lit for two or three hours after takeoff, and then meals are served. The lights are then dimmed for the remainder of the flight, until about two hours before arrival. But "when the duration of the flight gets longer and longer, this approach cannot work anymore, because this results in passengers being in darkness for 14 hours," Postnova says, making it harder for passengers to adjust to the time zone once they land.

To combat this, Postnova is designing interventions that can be used before, during, and after a flight. "It's the whole passenger journey experience," she says. One of her first suggestions was to change the in-flight light and meal service times to help travelers adapt to their destination's time zone. "Light is the key time cue for our circadian system," she says, "and if you align the lights correctly, then you can start adjusting while you are flying."



"This collaboration is absolutely unique," says neurophysicist Sveta Postnova.

Postnova is experimenting not only with timing, but *type* — like what kinds of onboard lighting would encourage wakefulness and sleep at the right times.

In 2019, Postnova traveled on a 19-hour research flight aboard a Boeing Dreamliner from New York to Sydney. The passengers served as test subjects for initiatives that Postnova and colleagues hypothesized would abate jet lag. By altering the type and timing of lighting, meals, and exercises, the travelers experienced less jet lag and were more alert after the flight, she says.

"I never thought, as a physicist, I would be presenting at press conferences with major airlines or going on a research flight," she says. "This collaboration is absolutely unique, and the experiences it has given me are very special."

Postnova recently received funding from the Australian government to expand her research with Qantas, but not all her work is aimed at the skies. She also studies circadian rhythms in shift workers, whose sleep cycles are often disrupted, and she's now modeling how aging affects sleep and cognitive performance.

"When I was doing my PhD, doing this type of biological modeling was still quite new and people didn't really believe it could go very far," she says. "But now it is widely accepted, and just seeing we can make an impact for everyday life is the biggest thing for me."

Alaina G. Levine is a professional speaker, STEM career coach, and author of the books Networking for Nerds (Wiley) and Create Your Unicorn Career (forthcoming).

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Recession, appeared to reflect economic strain across student demographic groups.

The recent downturn is tied more tightly to the largest demographic group in physics today and historically — young white men. As this group has diverted from bachelor's-level education, physics and fields with similar demographic profiles, like engineering, have felt the pinch.

Now, many physics departments are investing in cultural and curricular reforms that support groups historically underrepresented in physics, seeing these young people as an untapped source of scientific talent and innovation.

To learn more, *APS News* spoke with department chairs and faculty at institutions around the country. What do these experts think might boost enrollment?

Emphasize career connections

As tuition costs have far outpaced wage growth, many people aren't sure college is worth it, even though STEM degrees are among the most lucrative. According to Ben Zwickl, associate professor of physics and astronomy at Rochester Institute of Technology, physics faces an especially tricky challenge.

"Although physics is in STEM, we are not as clearly linked to a job as computer science or engineering," he says.

Colleges must do a better job of clearly connecting physics to diverse and well-paying career paths, Zwickl argues. "Students need to know that the debt they take on during undergrad has a hope of being paid off in a reasonable timeframe, and that it won't lower their quality of life over a long time period," he says.

An attendee at the 2023 March Meeting job expo. Credit: APS

With clearer routes to jobs, some students who might otherwise divert to engineering or computer science might choose physics instead. And learning about the path from a physics degree to employment might be particularly meaningful for first-generation college students, who are more likely to incur student debt than students with college-educated parents.

Change the physics curriculum

Some departments are also scrutinizing and reworking the physics curriculum. Several years ago, Florida International University (FIU) — named a Fulbright Hispanic-Serving Institution leader by the US State Department — asked the department to make changes that would help students graduate within four years. Because many FIU physics majors don't start off in the program — instead switching into it after enjoying the introductory physics required by other programs, like engineering — they must play catch-up, and often take longer to graduate.

"We needed to streamline the undergraduate physics curriculum," says FIU physics chair Werner Boeglin.

First, the department reduced the number of required two-semester course series. Two semesters of modern physics lectures and labs became one, for example. The department also gave students more leeway on which upper-division courses they could count toward their degree. "Since many of our students had already completed upper-division coursework in engineering, mathematics, or computer science, we decided to accept many of these 'applied physics' courses as physics electives," says Boeglin.

With fewer academic hurdles, FIU's physics program, whose undergraduate student body is two-thirds Hispanic or Latino, has seen "dramatically increased graduation rates," says Boeglin.

And with students graduating more quickly, FIU's undergraduate physics student body has shrunk — but for Boeglin, that's understandable. "You have the same influx, but now you have a bigger outflux," he says. Still, recruiting efforts have become increasingly important, even with FIU's strong reputation.

Although physics is in STEM, we are not as clearly linked to a job as computer science or engineering," Zwickl says.

Other departments are investing in new courses that broaden physics' appeal. For example, in "the quantum information science area, there are many new courses," Zwickl says. The courses are so new that faculty lack the right textbooks, and online communities have cropped up to share resources.

But new courses aren't always needed: Existing classes can teach new tools and applications. "Imagine an upper division theoretical course," Zwickl says. "You can swap out maybe 25% of the assignments and make them more computational. Then you're still giving problems in quantum mechanics or electricity and magnetism, but you're allowing students to explore those in more open-ended ways."

Zwickl also suggests incorporating more writing assignments into theory courses. "Maybe you'll lose a bit of content coverage, but [the students] actually go quite a bit deeper in some area and see how these theoretical ideas apply to some interesting system," he says. Plus, the students develop communication skills, one of the top five skills employers today want in STEM grads.

Because of accreditation requirements, engineering and computing programs have extensive industry partnerships. Those partnerships provide critical feedback and "keep the programs fresh," says Zwickl. As a result, engineering and computing programs "teach broadly relevant content, but also have an emphasis on teamwork and collaboration," he says. "It's something every employer says is important, and something that physics departments don't emphasize to the same degree."

Build community for students of color

In 1995, HBCUs graduated more than 1 in 2 Black physics majors — but in 2020, that number had fallen to 1 in 4. HBCUs have also seen declining enrollment in chemistry and engineering.

"Part of it is a high school issue — they're not feeding the pipeline," says Willie Rockward, physics chair at Morgan State University in Maryland. Because Black children in the US are more likely to attend socioeconomically disadvantaged schools, they're less likely to have dedicated physics courses, or teachers who know about physics careers and can point high-achieving math students toward physics, he says.

Rockward also points to the changing demographics of HBCU student and faculty bodies, which have become increasingly international and white. These shifts have changed the culture at many HBCUs, Rockward says. Given these trends, schools need to chart a path forward that ensures Black students still receive the support they need to succeed, regardless of who's teaching their classes, he adds.

"The biggest thing — and to me, it's low-hanging fruit, anyone can just pick it off the tree — is cohort recruiting," he says. "The main problem in physics is isolation. At some point, you get tired of being the only one." Rockward says cohort recruiting builds on the model of community. It has worked for HBCUs for decades, and it can work at predominantly white institutions as well, he says.

"If you can bring in three to five students from the same culture, the same ethnic group, per year or at least every other year, then that cohort helps them establish a community," he says. "Once you get that established . . . I promise, the problem begins to solve itself."

Help women identify as "physics people"

In just five years, from 2015 to 2020, the annual number of women graduating with a bachelor's in physics doubled. Women now earn 1 in 4 physics bachelor's degrees, and 1 in 5 faculty in physics and astronomy departments are women.

Students at the Conference for Undergraduate Women in Physics (CUWiP) at Northwestern University in 2019. Credit: CUWiP Northwestern

Anne Marie Porter, senior survey scientist at the American Institute of Physics, says she doesn't see any reason for these trends to slow. "We've heard from students that having women's support groups on campuses, meeting other women — whether they are faculty members or older graduate students — helps inspire them to persist in the field," she says.

But Porter says departments need to "address the factors that are making women feel like they can't do physics, or they're not welcome in that space."

"We want to make physics as encouraging and welcoming as we can. So, if women are not choosing physics, ideally, it's because there's something else they want to do, rather than feeling like they can't succeed in the physics field," she says.

Initiatives like STEP UP are designed to help young women identify as 'physics people,' so that more will pursue college-level physics. Efforts like these are important, Porter says, because they help women better understand what physics is and what they can do with it.

Offer a student-focused program

Rockward's plan to boost physics enrollment at Morgan State prioritizes the needs of his student body. "We're putting in place what I call the 'we care' model," he says. A core element of his plan — embracing the needs of Black students — could work at any school struggling to retain underrepresented students, he explains. At Morgan State, the faculty are "going beyond academic advising, to also focus on career advising . . . and connecting them to alumni."

"Giving the students that full-scale support structure seems to have been very successful," says Rockward, who also used this approach at Morehouse. He says departments need "champions" on the faculty who make it clear they're there to help Black students, or any students from underrepresented groups, succeed.

At FIU, many physics majors arrive less prepared than the average student enrolled at a better-funded school, says Boeglin. To help students succeed, "we provide a lot of help," he says — including by signing off on independent study courses, which gives students a chance to explore their individual interests. The students appreciate the one-to-one attention, and their graduate school applications are more successful, because faculty can write them stronger letters of recommendation, he says.

Boeglin also points out many Hispanic and Latino students at FIU have "very strong" family ties, and many work while attending school — factors that can make it harder for students to travel for conferences or internships. "Because we are a smaller program, we can take this into account," he says.

More broadly, Zwickl says that departments need to pay close attention to students' fears of failing out of a challenging major like physics. "I think for a long time, STEM departments were content to fail lots of students because there were always more to replace them," he says, which "treats students as a commodity, not as people."

"People don't make a commitment to go to college if they think 'I'm not going to finish this,'" he adds. "If our physics departments are not doing as well as they could with retention and graduation, then it should be a priority."

Zwickl suggests that departments looking to make changes consult APS's Effective Practices for Physics Programs (EP3) guide. The resource includes best practices to help departments improve and respond to challenges, including declines in funding and enrollment.

"Jobs are on the line," he says. "That's got to be the strongest incentive to change."

To future-proof your physics department, visit ep3guide.org.

Liz Boatman is a staff writer for APS News.

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potential follow-on to the National AI Initiative Act of 2020, which the committee helped develop. Committee member Jay Obernolte (R-CA), who has a master's degree in AI, is sponsoring the House version of the NAIRR legislation.

Meanwhile, science agencies have been pitching ideas to Congress on how they could contribute to a national push on AI. In particular, the Department of Energy published a report this summer that calls for DOE to tap its deep expertise in supercomputing to develop AI tools focused on scientific discovery, energy technology development, and national security. One of the lead authors, Rick Stevens of Argonne National Lab, participated in a Senate briefing on AI in July, along with DOE Under Secretary for Science and Innovation Geri Richmond and NSF Director Sethuraman Panchanathan.

Stevens told a DOE advisory committee this summer that the initiative is designed as a follow-on to DOE's roughly $2 billion program to deploy exascale computers, which will wrap up soon. The AI initiative could be much larger than the exascale effort, ultimately involving thousands of national lab scientists, Stevens said.

Asked how the initiative would be funded, given recent budget caps set by Congress, Stevens noted that Congress could provide emergency funding. Schumer has stated he will pursue follow-on legislation to the CHIPS and Science Act, which included $52 billion dollars for the semiconductor sector.

Mitch Ambrose is Director of FYI. Published by the American Institute of Physics since 1989, FYI is a trusted source of science policy news. Sign up for free emails at aip.org/fyi.

THE BACK PAGE

Is Climate Science Physics?

How we answer this question can help determine who understands, and who enters, the field.

BY NADIR JEEVANJEE

A photo, taken from the International Space Station on Sept. 10, 2018, of Hurricane Florence, which battered the Carolinas and southeastern US. *Credit: NASA*

Is climate science physics? As a theoretical physics graduate student at the University of California, Berkeley in the early 2010s, I hadn't given the question much thought. I read about climate change in the newspaper, but had the naive and condescending impression that Earth science was so much stamp collecting, and of little interest to a physicist.

That changed when I became a teaching assistant for Richard Muller's popular course, "Physics for Future Presidents." The course opened my eyes to the physical underpinnings of atmospheric science, climate change, and energy technology. After years of wandering the wilderness of theoretical physics, I grew excited about the prospect of applying the physics I loved to front-page problems.

When an ex-physicist turned up in Berkeley's Earth and Planetary Science Department and started probing for recruits, I decided to take the plunge, leaving the lofty heights of quantum gravity for the earthlier realm of atmospheric science.

The first step was to learn the basics, and I reveled in the application of fundamental physics to the climate — Navier-Stokes equations to atmospheric flow, Planck's radiation law to the greenhouse effect. It was a thrill to learn that Newton's laws applied as well to trade winds as it did to point masses, and that thermodynamics governed phenomena from cloud drops to thunderstorms.

But as the basic coursework waned and I turned to research, the honeymoon ended. Culture shock set in. Even though climate science was based in physics, it didn't *feel* like physics. The papers we read sometimes had no equations at all, and the arguments felt, at times, loose and hand-wavy. My job was to run computer simulations of the tropical atmosphere, but I had only ever worked with pencil and paper; it took me a week just to make a plot, and twice that to get the model to compile on the supercomputer. The climate science literature was summarized in thousand-page reports by the Intergovernmental Panel on Climate Change, which focused less on physics and more on historical records and model projections. In some instances, different models produce different projections, giving rise to "spaghetti plots" for variables like global mean surface temperature (Fig. 1).

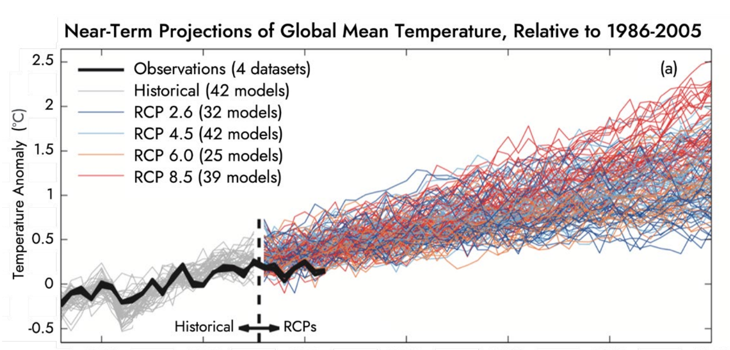

Figure 1: Model projections for global mean surface temperature, showing different future emissions scenarios. Broadly, the higher the RCP ("Representative Concentration Pathway"), the higher the greenhouse gas emissions. *Credit: Reproduced from Fig. 11.25 of IPCC 2013.*

I yearned for the elegance of physics, the Fermi problems and Feynman lectures, but found myself mired in spaghetti and Fortran instead. I wondered if I could muster the resolve to graduate, let alone continue in the field.

Eventually, however, I found my footing. Following the example of my advisor and many others, I learned to sniff out problems where back-of-the-envelope calculations could yield insight. (An early success: solving a Poisson equation that described how buoyant fluid parcels accelerate.) Obtaining results on my own gave me confidence that the gulf between physics and climate could be bridged, and that I could play a role.

I also realized that, on their own, these calculations were not enough. Unlike the idealized physical systems I studied as a student, Earth's climate is *complex*. With so many variables across so many scales, the climate behaves in ways that the underlying equations on their own can't predict, well-known as those equations might be. So climate scientists have developed model *hierarchies*, an array of modeling approaches that link to one another like rungs on a ladder. The simplest models look like textbook physics, solvable with pen and paper; the most complex require the world's largest supercomputers. For my physics-driven work to be meaningful, I had to connect it with the real-world complexity of comprehensive climate modeling.

Inspired, I crossed the country with my family to Princeton, New Jersey, to begin a fellowship at the Geophysical Fluid Dynamics Laboratory (GFDL). GFDL was an early nursery for climate science, and — in the 1960s and 1970s — produced the world's first climate models, pioneered by GFDL scientist and Nobel Prize winner Syukuro Manabe. Moving to GFDL meant working in The Room Where It Happens — where algorithms are developed and models run, and where the complexity of climate science is both a familiar fact and constantly debated.

Outside the lab walls, however, conversation was eroding. Princeton University itself was home to several skeptical physicists, and communication between them and Princeton's climate scientists, to the degree it had ever existed, had broken down. On the national level, apocalyptic doomsaying and righteous denial sailed past each other on the airwaves, and trust in science felt dangerously low.

These tensions reinforced my suspicion that the complexity of Earth's climate was an issue not just for climate modeling but also for climate *communication* — both for our colleagues in physics and for the public. Uncomfortable just burying my head in research, I wanted to try to reach both audiences.

In 2019, a few colleagues and I formed a group called Climate Up Close and made it our mission to speak with ordinary people, far from academic centers. We ventured out into the country, to central Pennsylvania and the Florida panhandle, and held events in churches, synagogues, and libraries. We tried to dispel misinformation, answer questions, and build trust with our willingness to listen. It was an effort to close the gap with the public.

But what about the gap with physicists? I wondered if the simple models my physicist's heart sought might also be a communication tool. If key aspects of climate science could be explained on a blackboard, à la Fermi and Feynman, could this help hesitant colleagues understand it? My mentors liked the idea, and encouraged me to offer a handful of lectures at Princeton on the "physics of climate." No PowerPoint spaghetti — just chalk on blackboard. The turnout was overwhelming, and made clear that many colleagues yearned to bridge this gap, too.

I realized that explaining climate science to the public, or to physicists down the hall, required starting where I had as a graduate student: With clear, simple essentials. Of course, in climate science, the reductionist approach so vaunted in physics must be married to an acceptance of the Earth's complexity — but to climb a ladder, it helps to start on the bottom rung.

While the lectures were a success, the pandemic put a halt to the outreach. My colleagues and I buried our noses in research. But then, a miracle occurred: The 2021 Nobel Prize in Physics was awarded to climate scientists, including GFDL's Suki Manabe, the father of climate modeling. Climate science now had pride of place in physics. GFDL scientists gathered for a week to celebrate, our pride compounded by the joy of gathering in person for the first time in a year and a half.

In the months after, I found myself invigorated. My mentors and I wrote a retrospective on Manabe's key paper, detailing his ingenious distillation of the essential elements of climate into a 1-D model that produced the first credible simulation of global warming. I turned back to my lecture notes for the "physics of climate," expanding them to show how Manabe's results could be sketched on a blackboard. I joined APS's Topical Group on the Physics of Climate, itself energized by the 2021 Prize and actively organizing events and lectures. The Nobel committee had sent a clear message to the world, and I was running with it.

So, yes — climate science is physics. Earth obeys the laws of fluid mechanics, thermodynamics, and radiative transfer, and these laws are encoded in the climate models that have led to consensus. But to understand the Earth system, we need that hierarchical ladder — models familiar to physicists on the bottom rung; models of intermediate complexity, like Manabe's 1-D model, on the middle rungs; and global climate models, like GFDL's, on the top rung. Moving between rungs requires a physicist's penchant for identifying what is essential and what is not. And this ability to cut through complexity is also what's needed to communicate climate science, to both the public and fellow scientists, and build trust and confidence in our results.

In this sense, climate change is a physics problem *par excellence*: take several fields of physics, link them across an enormous range of scales, and then parse what emerges. This is a challenge worthy not only of our best Earth scientists, but our best physicists. Recognition is spreading: For example, this year's candidates for the APS presidential line are both climate physicists.

But on the ground, obstacles remain. Climate scientists in the US are rarely housed in physics departments, and there is little support for young physicists to transition into climate science, as I did. But I'm optimistic that physics departments and funding agencies will also soon answer the call to bridge the gap — once they realize that climate science is physics, and that physicists themselves can help make that clear.

Nadir Jeevanjee is a physical scientist at the Geophysical Fluid Dynamics Laboratory at the National Oceanic and Atmospheric Administration (NOAA). He holds a PhD in physics from the University of California, Berkeley.

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